A Multi-Lab Integrated Observation and Modeling Approach to Understanding Land-Atmosphere Interactions: A *Bedrock-to-Boundary Layer (B2B)* Approach

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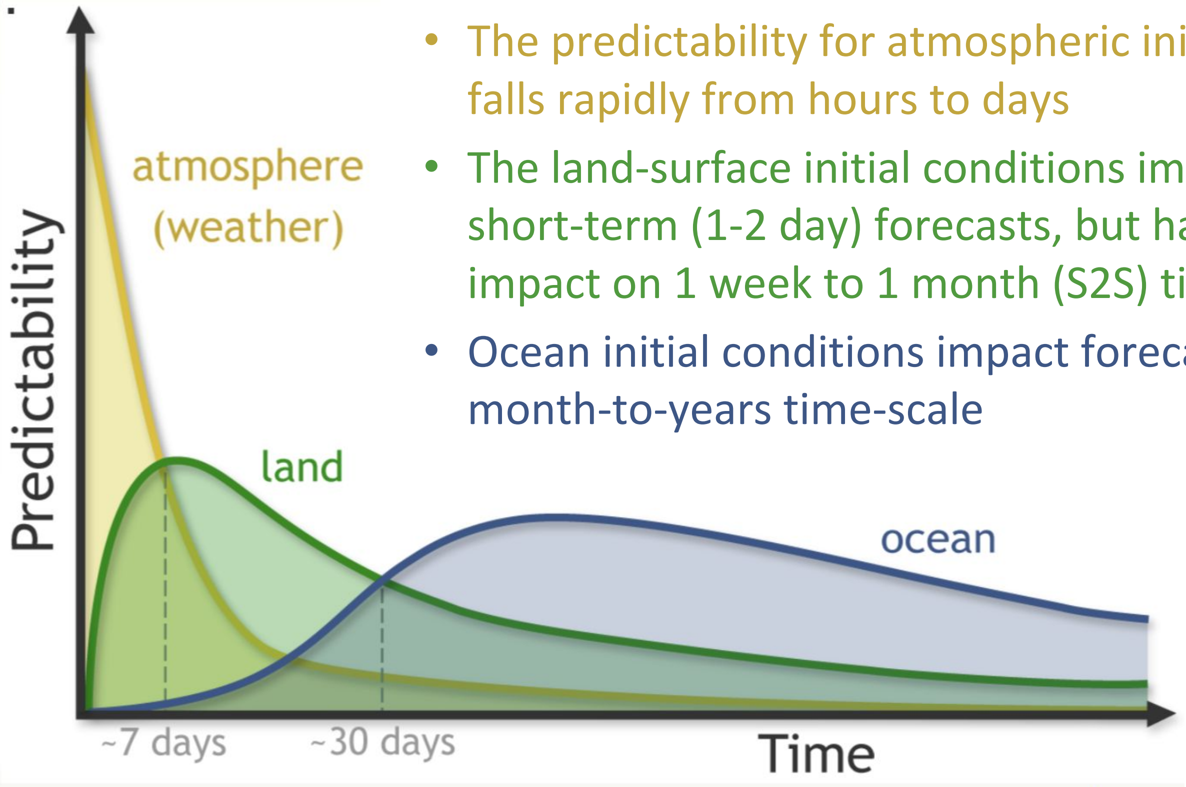
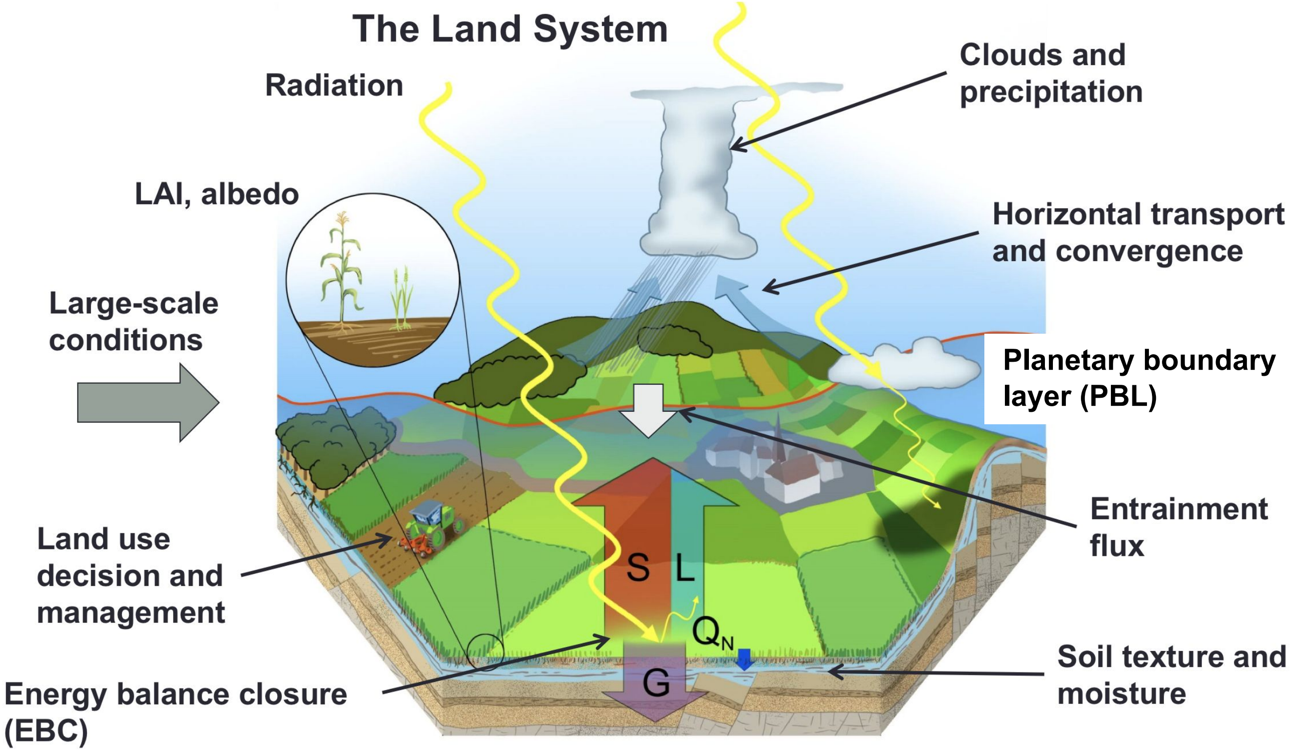
Predictability vs. Initial Conditions



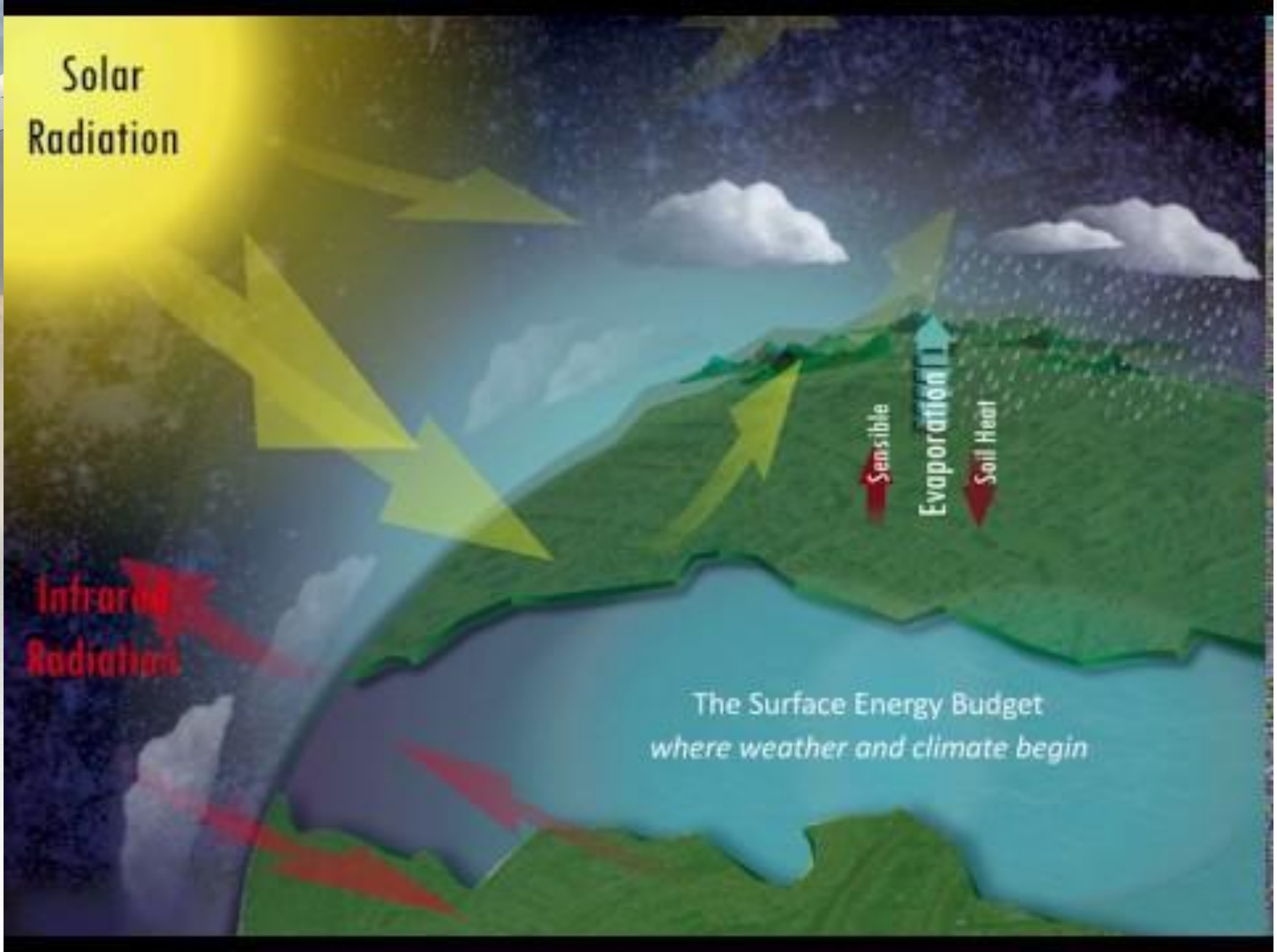
- The predictability for atmospheric initial conditions falls rapidly from hours to days
- The land-surface initial conditions impacts short-term (1-2 day) forecasts, but has largest impact on 1 week to 1 month (S2S) time-scales
- Ocean initial conditions impact forecasts at the month-to-years time-scale

The Complexity of the Land System

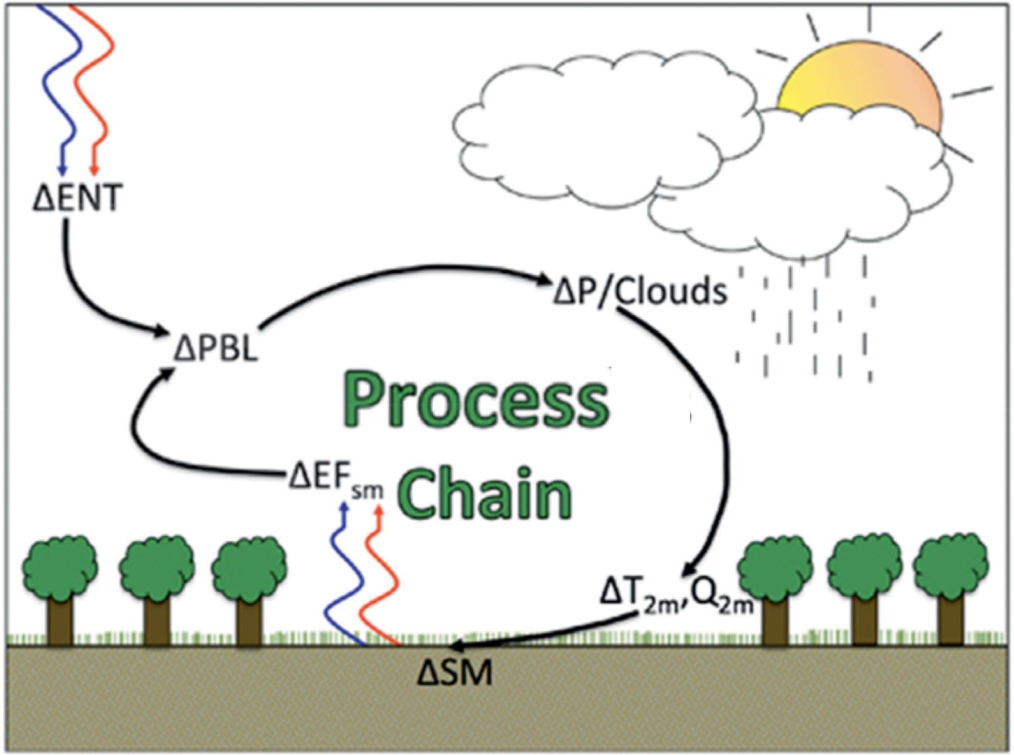


Water and energy budgets are results of feedback processes in the LA system

Wulfmeyer et al BAMS 2018


Solar Radiation
Sensible
Evaporation
Soil Heat
The Surface Energy Budget
where weather and climate begin

A Simplified Land-Atmosphere Process Chain



$$\Delta SM \xrightarrow{(a)} \Delta EF_{sm} \xrightarrow{(b)} \Delta PBL \xrightarrow{(c)} \Delta ENT \xrightarrow{(d)} \Delta T_{2m}, Q_{2m} \rhd \Delta P/Clouds$$

Santanello et al BAMS 2017

Land-Atmosphere Feedback Has 2 Legs

$\Delta P \Rightarrow \underbrace{\Delta SM \rightarrow \Delta Fluxes}_{\text{Terrestrial leg}} \rightarrow \Delta PBL \rightarrow \Delta P$

Feedback loop: Terrestrial leg Atmospheric leg

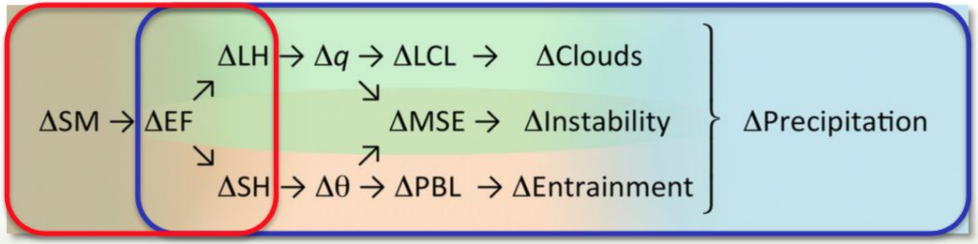
- Terrestrial – When/where/how does soil moisture (vegetation, snow, etc.) control the partitioning of net radiation into sensible and latent heat fluxes?

In many models, the coupling in the terrestrial leg is **too strong**

- Atmosphere – When/where do surface fluxes significantly affect boundary layer properties, clouds and precipitation?

And the atmospheric leg is **too weak**

Process chains:



COLA Center for Ocean-Land-Atmosphere Studies GEORGE MASON UNIVERSITY

Land-Atmosphere Science: Non-traditional Path

- Land surface models (LSMs) were initially developed to provide boundary conditions for atmospheric models
  - There were few observations of land surface or L-A interactions available for the development of these models
- These early LSMs consisted of fairly simple conceptual models or empirical relationships – only recently have there been coordinated measurements to evaluate LSMs
  - But very few complete datasets to really look at L-A processes…
- Today, more observations are available to evaluate and improve these models
  - Need to have cohesive plans to evaluate both the atmospheric and terrestrial legs
  - Need observations over a range of different soil types, land surface types (e.g., desert, conifer forest, grassland, etc), and weather conditions
- *Long-term datasets are needed to tease out the physical relationships, especially since which processes that are active are functions of soil moisture (which is usually dependent on precipitation), atmospheric moisture content, net radiation, etc.*

OAR Labs are Individually Addressing Portions of the Land-Atmosphere Problem

- ARL: relating surface heat fluxes to soil profiles, impacts on dispersion and air quality
- GMD: shortwave and longwave radiative fluxes (upwelling and downwelling), carbon cycle impacts
- CSD: turbulence and winds in the PBL, air chemistry
- PSD: turbulence, stability, and humidity in the PBL, clouds and precip
- GSD: operational weather forecasts (HRRR), S2S modeling
- NSSL: convective initiation, precipitation

OAR Labs are Well-Positioned to Address L-A Qs

- L-A studies need to include both observational and modeling components
  - Modeling at multiple spatial (10s of m to 10s of km) and temporal (hours to weeks) scales

    GSD, ARL, CSD, NSSL
  - Observations of land-surface (e.g., soil moisture and temperature profiles from surface to below root zone, soil type)

    ARL, PSD
  - Observations of the planetary boundary layer (surface to top of the PBL which is typically 1-2 km) of profiles of temperature, humidity, wind, turbulent motions

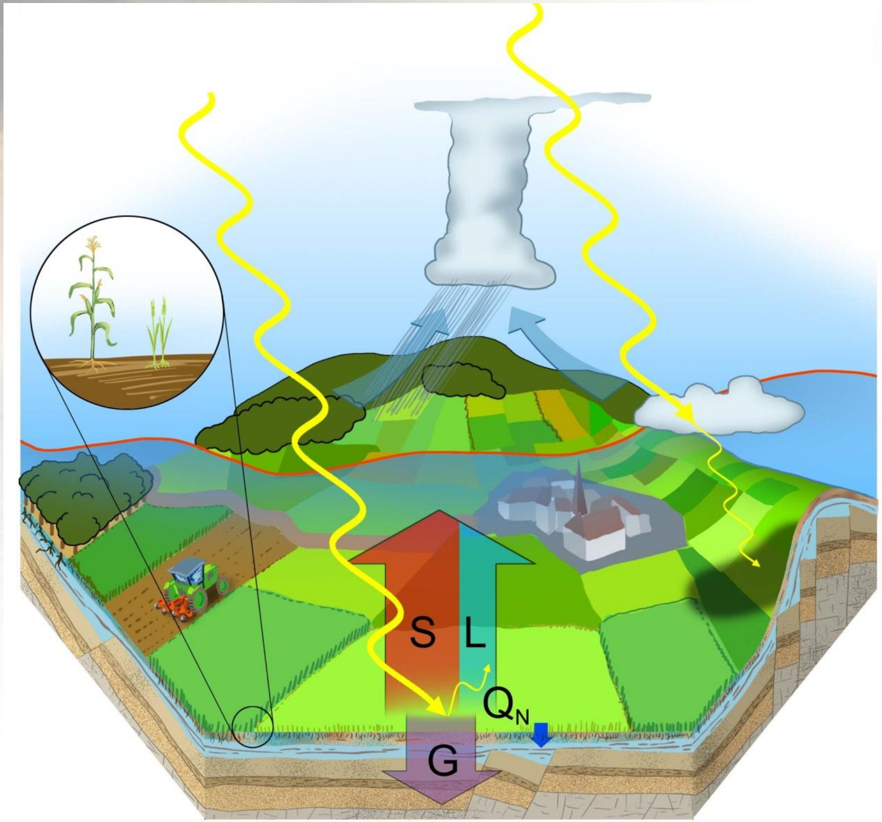
    CSD, PSD, NSSL
  - Observations in the surface layer that couples the PBL to LS: sensible and latent heat fluxes, upwelling and downwelling radiation (both LW and SW), canopy height, leaf-area index, precipitation amount

    GMD, ARL

OAR's Observational Resources

PSD measures winds (10 radar wind profilers), temperature and humidity profiles (2 MWRs), surface met (20 stations), cloud properties (cloud radar), and precip (6 disdrometers)

ARL measures surface latent, sensible and ground fluxes (6 SEB stations) and periodic UAS flights to look at representativeness



NSSL measures profiles of temperature and humidity (2 CLAMPS), and precipitation (NOXP, disdrometers)

CSD measures wind and turbulence profiles with 5 Doppler lidars

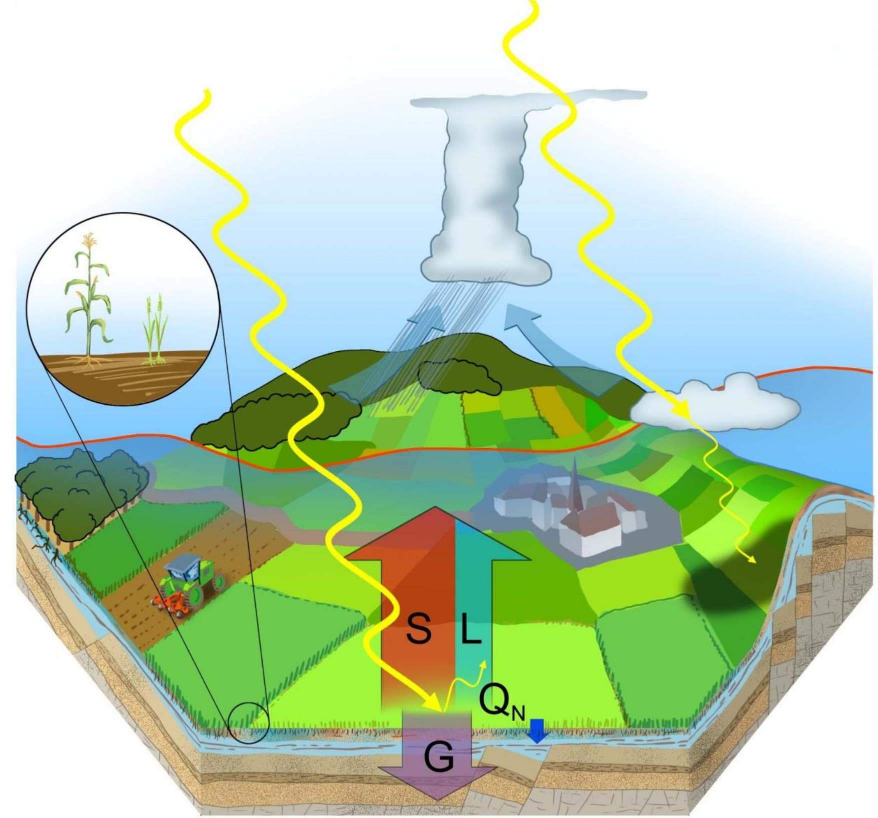
GMD measures radiative fluxes with 2 mobile SURFRAD and 3 RADSYS systems

OAR’s Modeling Capability

GSD: operational mesoscale and storm-scale modeling, S2S modeling

PSD: Mesoscale and S2S modeling

ARL: Large-eddy simulation modeling and dispersion modeling



NSSL: Regional modeling (primarily towards severe Wx)

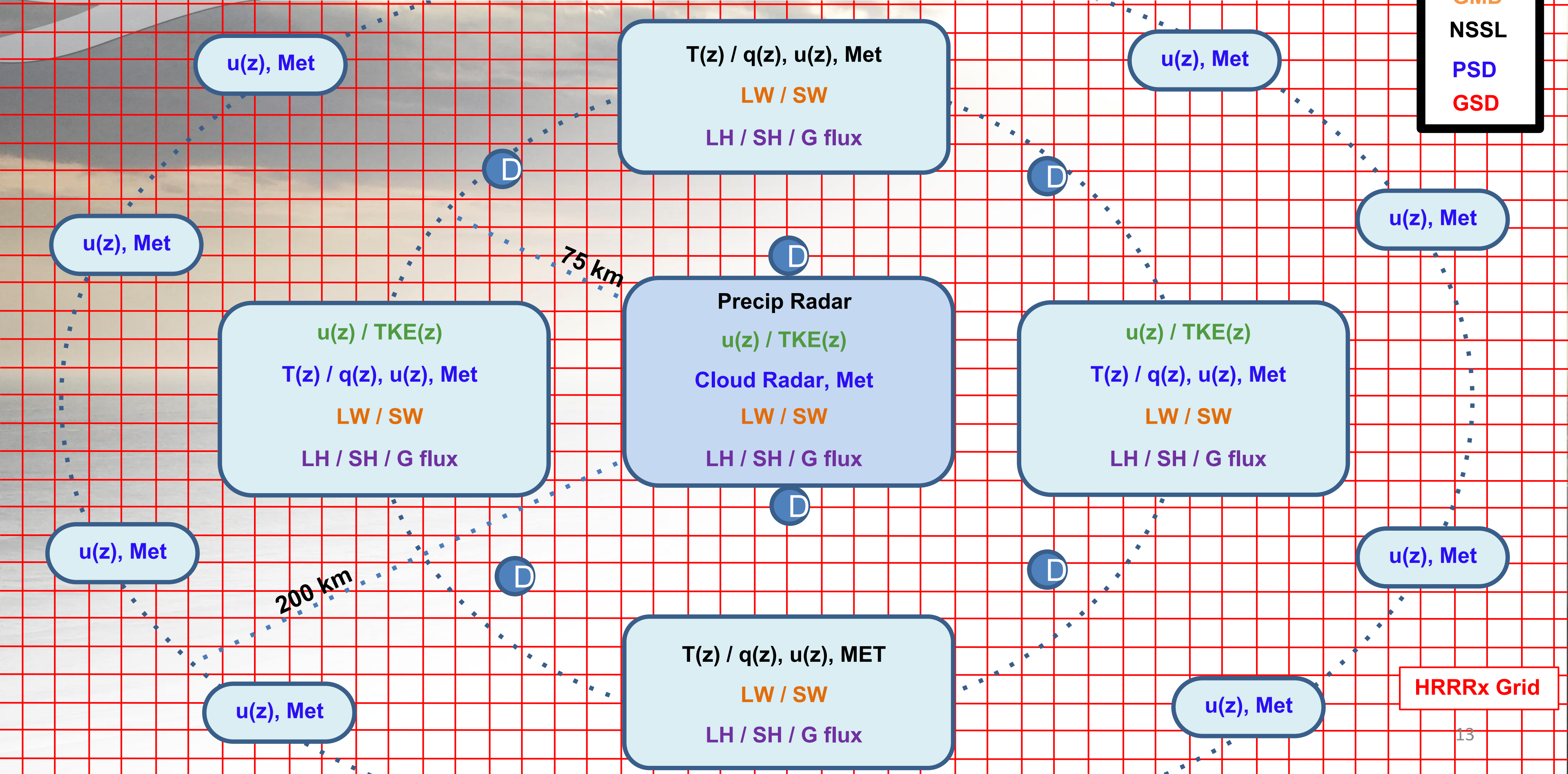
CSD: Large-eddy simulation and regional modeling

GMD: Regional modeling (primarily towards carbon cycle)

The Problem: L-A Research is Not Coordinated

- There is a strong need: improved S2S forecasts require better treatment of L-A interactions (this is an O2R driver)
- Each lab works (largely) independently to address its mission
- Instruments needed to study L-A interactions are dispersed among different OAR labs
- A cohesive science plan that integrates the activities of the different labs does not exist
  - Workshop on L-A is one idea (more in a few minutes on this)
- Objectives
  - Identify a set of Qs and an obs + modeling research plan that addresses L-A deficiencies
  - Prioritize locations where these datasets and modeling studies should occur
  - Commit: Deploy observations and modeling capability
- Side effect: these datasets will help each lab with its own mission
  - If you build it, they will come --- other questions can be addressed outside the L-A focus
- Challenge is funding: why would Lab Z keeps its instruments deployed when only observations in a particular set of conditions are needed for its mission?

A Strawman Deployment Scheme



L-A Workshop

- Bring together small number of scientists from each lab
  - Want to keep total participation manageable (less than 25)
- Objective #1: Identify a set of Qs and an observational + modeling research plan that addresses L-A deficiencies
- Objective #2: Prioritize locations where these datasets and modeling studies should occur
- Objective #3: Summarize in a whitepaper
- Timeframe: February-March 2019
- Two days at ESRL in Boulder

Our Hope:

Our Hope: Working Together We Solve the Puzzle